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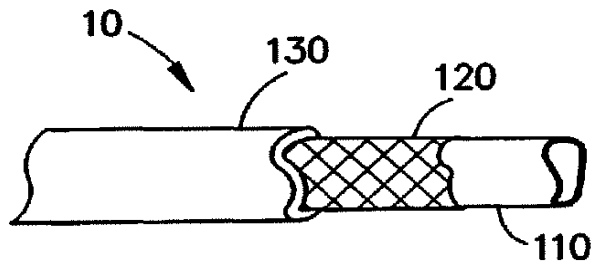
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preferably reinforced with specific textile reinforcement materials that permit a lower thickness of plastic to be utilized than is generally required to withstand high pressure situations and also serve to prevent propagation of any cracks which may develop within the thermoplastic or thermoset materials. Such pipes exhibit an elongation at break in relation to that provided by the textile reinforcement and not with regard to the same type of elongation at break characteristic for the thermoplastic or thermoset composition.

(57) Abstract: Novel thermoplastic pipes which can withstand internally generated and/or applied pressures for utilization within, primarily, underground liquid and gas transport systems are provided. Such pipes are improvements over standard metal (i.e., steel, lead, and the like) pipes due to construction costs, shipping costs, implementation costs (particularly underground), flexibility (and thus modulus strength allowances) to compensate for underground movements (i.e., earthquakes and tremors), non-rusting characteristics, reduced crack propagation possibilities, and ease in manufacture. Such pipes are

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NOVEL TEXTILE REINFORCED THERMOPLASTIC OR THERMOSET PIPES AND METHODS OF MAKING THEREOF

Field of the Invention

5 The present invention generally relates to novel thermoplastic or thermoset pipes which can withstand a varied range of internally generated and/or applied pressures, including high pressures (up to 100 bars pressure for utilization within, primarily, underground liquid and gas transport systems) and medium pressures (pipes of at most 5 millimeters in thickness which can withstand a varied range of internally generated
10 and/or applied pressures up to at least 5 bars, preferably at least 20 bars, for utilization within, primarily, liquid transport systems). Such pipes are improvements over standard metal (i.e., steel, lead, and the like) pipes due to construction costs, shipping costs, implementation costs (particularly underground), flexibility (and thus modulus strength allowances) to compensate for underground movements (i.e., earthquakes and tremors),
15 non-rusting characteristics, reduced crack propagation possibilities, and ease in manufacture. Such pipes are preferably reinforced with specific textile reinforcement materials that permit a lower thickness of plastic to be utilized than is generally required to withstand high pressure situations and also serve to prevent propagation of any cracks which may develop within the thermoplastic or thermoset materials. Such pipes exhibit
20 an elongation at break in relation to that provided by the textile reinforcement and not with regard to the same type of elongation at break characteristic for the thermoplastic or thermoset composition. A simplified, potentially on-site production method for producing more uniform, better-performing pipes as well as a specific molding dorn for such a purpose are also contemplated within this invention.

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Background of the Invention

Underground transport of liquids and gases has been utilized for many years. Such underground transport has proven to be the most efficient and safest manner in which to transport potentially explosive, flammable, and/or toxic liquids (such as crude
30 oil, for example) and gases (such as methane and propane, as examples) long distances. The principle method followed to provide such long distance underground transport has been through metal tubes and pipes. In the past, the utilization of metals (such as steel,

copper, lead, and the like) was effective from cost and raw material supply perspectives. However, with the population growing throughout the world and the necessity for transporting liquids and gases to more remote locations increases, the continued utilization of such metal articles has become more and more difficult for a number of reasons. Initially, the production of such metal tubes and pipes must be undertaken through high-temperature production methods at specific foundries which are normally located a substantial distance from the desired installation site. Such off-site production thus requires transport of cumbersome metal articles to the installation location and then subsequent placement into already-dug channels. These procedures are, again, difficult to follow since metal articles are rather heavy and must be connected together to form the desired pipeline. Additionally, in order to reduce the number of connections between individual pipes, longer metal pipes could be formed, which adds to the complexity with an increase in required welded connections. Further problems associated with metal pipes and tubes include, without limitation, the potential for rusting (which may contaminate the transported liquid or gas), the low threshold of earth-shifting which could cause a break within the pipeline, and the difficulty in replacing worn out metal pipes in sections, again due to the metal pipe weight, metal pipe length, and connection welds. These break problems have proven to be extremely troublesome in certain geographic areas which are susceptible to earthquakes and tremors on a regular basis. When such unexpected quakes have occurred in the past, the metal gas and liquid pipelines have not proven to be flexible enough to withstand the shear forces applied thereto and explosions, leaks, or discontinued supplies to such areas have resulted. These metal articles have remained in use because of their ability to withstand high pressures. Furthermore, although such metal pipes are designed to withstand such high pressures (i.e., above 80 bars, for instance), once a crack develops within the actual metal pipe structure, it has been found that such cracks easily propagate and spread in size and possibly number upon the application of continued high pressure to the same weakened area. In such an instance, failure of the pipe is therefore imminent unless closure is effectuated and repairs or replacements are undertaken.

Although there is a need to produce new pipelines to remote locations around the world, there is also a need to replace the now-deteriorating pipelines already in use. Aging pipelines have recently caused great concern as to the safety of utilizing such old

articles. Unexpected explosions have occurred with tragic consequences. Thorough review and replacement of such old metal pipes is thus necessary; however, due to the difficulties in determining the exact sections of such pipelines which require replacement, there is a desire to completely replace old pipelines but following the same exact routes. Again, due to the difficulties noted above, there is a perceived need to develop more reasonable, safer, longer-lasting, easier-to-install, non-rusting, non-crack propagating, and more flexible pipeline materials. To date, there have been some new thermoset or thermoplastic articles which are designed to withstand rather low pressure applications (i.e., 20 bars or below) and which include certain fiber-wound reinforcement materials (including fiberglass, polyaramids, polyesters, polyamides, carbon fibers, and the like). However, the resultant articles do not include specific textile reinforcements (they are fibers wound around specific layers of plastic material) and thus are difficult and rather costly to produce. Furthermore, such fiber-wound materials cannot be easily produced at the pipe installation site again due to the complexity of creating fiber-wound reinforcement articles subsequent to thermoplastic or thermoset layer production. Additionally, with such off-site production, transport and in-ground placement remain a difficult problem. Thus, although some improvements have been provided in the past in relation and in comparison to metal pipes and tubes, there simply is no viable alternative presented to date within the pertinent prior art which accords the underground liquid and gas transport industry a manner of replacing such high pressure metal articles.

Furthermore, even though such plastic rigid pipes exhibit desirable degrees of flexibility, they also generally suffer from such flexibility simultaneously. For example, when such pipes are handled and are supported at only one or two points along their lengths (e.g., during lifting of a long pipes at two ends) the self-weight of the pipes causes bending or bowing longitudinally to create such problems as buckling and potential failure of the pipe wall. In addition, external forces such as during storage or loading also tends to flex or bend the pipe longitudinally to potentially create the same problems.

Thus, it is highly desirable to determine a fabricating operation and final pipe product that can result in improved products to withstand such forces and prevent longitudinal bending or bowing, particularly in a cost effective manner. To date, such problems have not been solved for thermoplastic or thermoset rigid pipes effectively.

Objects of the Invention

It is thus an object of this invention to provide such a viable alternative method for replacing or overcoming the shortcomings and difficulties of high pressure (i.e., from about 20 to about 100 bars) or medium pressure (i.e., from about 5 bars to about 20 bars pressure) underground metal pipes and tubes.

Another object of this invention is to provide a suitable fabric reinforcement system which permits a relatively low amount of thermoplastic or thermoset composition to be utilized in order to produce a pressure-resistant thermoplastic pipe article.

Yet another object of this invention is to provide an interlocking mechanism to best ensure the textile reinforcement layer remains in place during and after introduction of the outer thermoplastic or thermoset layer.

Still another object of this invention is to provide a suitable simplified method of producing such a textile-reinforced thermoplastic pipe article.

Another object of this invention is to provide a suitable fabric reinforcement system which permits a relatively low amount of thermoplastic or thermoset composition to be utilized in order to produce a pressure-resistant thermoplastic pipe article.

Another object of this invention is to provide a suitable fabric reinforcement system which permits a relatively low amount (at most about 5 millimeters wall thickness) of thermoplastic or thermoset composition to be utilized in order to produce a pressure-resistant thermoplastic pipe article.

Yet another object of this invention is to provide an interlocking or interfolding mechanism to best ensure the textile reinforcement layer remains in place during and after introduction of the outer thermoplastic or thermoset layer.

Yet another object of this invention is to provide an interlocking mechanism to best ensure the textile reinforcement layer remains in place during and after introduction of the outer thermoplastic or thermoset layer.

Still another object of this invention is to provide a suitable simplified method of producing a resinous pipe article of substantial uniformity in wall thickness and shape as well as, if such article includes a reinforcement material, greater degrees of adhesion between the resin component and reinforcement component of such pipes.

Also, another object is to provide a novel dorn article for the purpose of initially applying reinforcement material to resin component which then cools as the combined

materials move along the dorn to form the aforementioned uniform and greatly adhered together article.

Alternatively, the dorn may be utilized on a resin component alone to provide a uniform shape and/or wall thickness for the resultant pipe, if desired.

- 5 Furthermore, an object of this invention is to provide reinforced thermoplastic or thermoset pipes that withstand longitudinally placed stresses and forces and thus do not exhibit appreciable bending or bowing in reaction to internal or externally applied forces or normal and/or expected pressures.

10 **Summary and Brief Description of the Invention**

- Accordingly, this invention encompasses a pipe comprising at least two distinct layers of thermally manipulated polymeric material and at least one layer of textile reinforcement material, wherein said textile reinforcement material is sandwiched between said two distinct layers of said thermally manipulated polymeric material,
- 15 wherein the elongation at break exhibited by such a pipe is limited solely to the elongation at break exhibited by said textile reinforcement material, and wherein said textile reinforcement material exhibits an elongation at break of at most 20%, preferably at most 15%, more preferably at most 10%, and most preferably at most 6%. Preferably said pipe is constructed to withstand at least 100 bars of internal pressure before
- 20 exceeding the elongation at break limit. An alternative yet also preferred embodiment is a pipe which exhibits at most 20 bars of pressure of internal pressure before exceeding the elongation at break limit and a wall thickness of said polymeric material of at most 1/11th of the diameter of said pipe, preferably at most about 1/15th, more preferably at most about 1/20, and most preferably at most about 1/25th. Also contemplated within
- 25 this invention is the pipe as noted above wherein the textile reinforcement material introduced within said pipe is a flat structure having a first side and a second side which is formed into a tubular structure around the inner polymeric layer upon overlapping contact of said first and second sides and which possesses means to adhere or interlock said overlapped first and second sides.

- 30 Also encompassed within this invention is a pipe comprising at least one layer of thermally manipulated polymeric material and at least one layer of at least one textile reinforcement material, wherein said thermally manipulated polymeric material exhibits

an average wall thickness for said pipe of at most 5 millimeters, wherein said pipe exhibits a pressure resistance of at least 20 bars (either from internally generated or externally generated pressures), and wherein the elongation at break exhibited by such a pipe is limited solely to the elongation at break exhibited by said textile reinforcement material. The elongation at break of such reinforcement material is at most 50%, preferably at most 30%, more preferably at most 20%, still more preferably at most 15%, even more preferably at most 10%, and most preferably at most 6%. Preferably said pipe, having such thin walls, is constructed to withstand at least 20 bars of internal pressure, as noted above, before exceeding the elongation at break limit. An alternative yet also preferred embodiment is a pipe which exhibits at most 20 bars of pressure of internal pressure before exceeding the elongation at break limit, and a wall thickness of said polymeric material of at most 1/15th of the diameter of said pipe, preferably at most about 1/25th, more preferably at most about 1/50, and most preferably at most about 1/100th, with the proviso that the wall thickness itself cannot exceed 5 millimeters (and thus the diameter of the subject pipe can be as much as about 500 millimeters, at its greatest). Also contemplated within this invention is the pipe as noted above wherein the textile reinforcement material introduced within said pipe is a flat structure having a first side and a second side which is formed into a tubular structure around the inner polymeric layer upon overlapping contact of said first and second sides and which possesses means to adhere or interlock said overlapped first and second sides, as well as a multiple layer resin component and multiple textile reinforcement components contacted together to provide the desired pressure resistance.

Further encompassed within this invention is a method of producing a resinous pipe comprising at least one layer of thermally manipulated polymeric material, wherein said polymeric material is first heated and applied around a first end of a molding dorn having a first end and a second end as well as areas in between, and subsequently moved along the length of said dorn to said second end of said dorn and eventually cooled, wherein said dorn exhibits the shape diameter throughout its entire structure, but exhibits a greater surface area at said first end than at said second end. Preferably, said dorn also exhibits a reduction in surface area numerically from said first end through all areas in between said first end to second end and ultimately to said second end. Preferably, said second end is perfectly round in shape. Clearly, if the first end of the dorn must have a

greater surface area (with the same diameter as the second end), then it must exhibit a roughened surface or, at least, indentations throughout. The term "diameter" in such an instance is intended, for the first end, to indicate the greatest distance from the greatest extension of the surface (at its greatest measure from the middle of the dorn) to the surface exactly opposite. In order to provide the desired uniformity of shape and wall thickness, such diameter must be the same as that of the second end (which should be substantially round, as noted above). Without such a specific diameter, such uniformity would not be possible, as the walls would not remain at the same thickness at all points on the dorn. More importantly, however, once the resin is applied around the dorn itself, if the overall diameter of the dorn is altered, the resultant molded pipe will exhibit the aforementioned problems of non-uniform wall thickness or uneven shape. The pipe made therefrom said method and therewith said dorn comprises at least one layer of textile reinforcement material, adhered to at least one thermally manipulated polymeric material or, preferably such textile reinforcement material is sandwiched between at least two distinct layers of such thermally manipulated polymeric material, wherein the elongation at break exhibited by such a pipe is limited solely to the elongation at break exhibited by said textile reinforcement material, and wherein said textile reinforcement material exhibits an elongation at break of at most 50%, preferably at most 30%, more preferably at most 20%, still more preferably at most about 15%, even more preferably at most about 10%, and most preferably at most 6%.

Additionally, another broad aspect encompassed within this invention is a substantially rigid pipe having a wall formed from a thermally manipulated polymer material including a plurality of elongate reinforcing elements embedded in the thermally manipulated polymeric material of the pipe wall, wherein the reinforcing elements are arranged to extend in a direction substantially longitudinally of the pipe and are adapted to stiffen the pipe against longitudinal bending. In one form of the invention the elongate reinforcing elements may extend at a slight angle in the range of 0° to 20° with respect to the longitudinal axis of the pipe.

In a preferred form of the invention the reinforcing elements are arranged in at least one layer, with each layer embedded at a substantially fixed or constant depth within the pipe wall. In the event that there is only a single layer of reinforcing elements, it is desirable that the layer be located radially outwardly, proximate the outer surface of the

pipe wall. More preferably, however, the pipe includes at least two layers of reinforcing elements, with each of the at least two layers being substantially spaced apart across the width of the pipe wall. In a highly preferred form of the invention the innermost layer of reinforcing elements is embedded proximate an outer surface of the pipe wall. This
5 spacing of the reinforcing layers enhances the overall stiffening effect. In addition, the inward location of at least one layer can also be useful to also provide a degree of radial reinforcement for the pipe.

In another preferred form of the invention the elongate reinforcing elements of each layer are interconnected with one another. This interconnection of the reinforcing
10 elements is preferably achieved by their incorporation in a fabric material. The fabric may be formed according to a variety of known textile constructions including woven, knitted, laid, non-woven, stitched or any combination thereof and it may optionally have a relatively open mesh configuration. The elongate reinforcing elements are themselves preferably comprised of textile fibers. For example, the reinforcing elements may be
15 textile yarns or cords. By incorporating a plurality of the reinforcing elements in a fabric it is possible to apply or embed a collection of the reinforcing elements (for example a complete layer) in a single operation. Preferably, the reinforcing elements and/or the fabric material containing those elements are coated and/or treated with a substance to promote adhesion of the reinforcing elements within the polymer matrix of the pipe wall.

20 The term "thermally manipulated polymeric material" is intended to encompass the well known polymeric compositions of a) thermoplastics and b) thermosets. Such terms are well known and describe a) any synthetic polymeric material that exhibits a modification in physical state from solid to liquid upon exposure to sufficiently high temperatures and b) any synthetic polymeric material that exhibits orientation in a
25 preselected configuration upon exposure to sufficiently high temperatures. Most notable of the preferred thermoplastic types of materials are polyolefins (i.e., polypropylene, polyethylene, and the like), polyester (i.e., polyethylene terephthalate, and the like), polyamides (i.e., nylon-1,1, nylon-1,2, nylon-6 or nylon-6,6), and polyvinyl halides (i.e., polyvinyl chloride and polyvinyl difluoride, as merely examples). Preferred within this
30 invention are polyolefins, and most preferred is polypropylene. Such materials are generally petroleum byproducts and are readily available worldwide. These materials are produced through the polymerization of similar or different monomers followed by the

melt extrusion of the polymerized materials in pellet form into the desired shape or configuration. Upon solidification through cooling, such materials exhibit extremely high pressure resistance, particularly upon introduction of nucleating agents, such as substituted or unsubstituted dibenzylidene sorbitols, available from Milliken & Company under the tradename Millad®, and/or certain sodium organic salts, available from Asahi Denka under the tradename NA-11™. Such nucleating agents are either mixed and provided within the pelletized polymers, or admixed within the melted polymer composition prior to extrusion. These compounds provide strength enhancements and accelerate thermoplastic production by producing crystalline networks within the final thermoplastic product upon cooling at relatively high temperatures. Theoretically, at least, with a stronger initial thermoplastic product, the more durable and potentially longer functional lifetime provided by such a product. Preferred thermoset materials include materials such as polyurethane, polycarbonate, or the like.

Since pipe diameters utilized for largescale underground transport applications are generally measured in feet rather than inches or millimeters, the wall thicknesses required to provide the desired high pressure characteristics are extremely high for thermoplastics or thermosets alone. Although such thermoplastic and/or thermoset materials provide certain pressure resistances, in general the wall thickness required to withstand pressures of about 80 bars requires a standard diameter to wall thickness ratio of at most 11:1 (for polyethylene for example). Thus, in order to provide such high pressure characteristics without exceeding the elongation at break limits of the polymeric materials present in pipe form (i.e, substantially cylindrical), with pipe diameter of, for example, about 232 millimeters (about 9 inches), the wall thickness of the pipe must be at least about 21 millimeters, or about 0.85 inches) to withstand such high pressures. Even with such thick walls, the polymeric materials would not provide any resistance to crack propagation should a weakened area of the pipe produce such a burst point. There is a strong desire to increase the pressure resistance (and thus consequently, the elongation at break characteristics) of the target polymeric pipe material in order either to provide much thinner wall thicknesses without a loss in pressure resistance as compared with the standard polymeric materials alone, or to provide greater pressure resistant thick-walled pipes which are more reliable upon exposure to very high pressure situations. Such desirable benefits have been unavailable through practice of a relatively

simple manufacturing method with actual textile reinforcement materials providing the basis of pressure resistance for the entire pipe article.

Apparently, upon application of internal pressure within such non-reinforced thermoplastic and/or thermoset piping materials, the materials expand in the direction dictated by the pressure therefore thinning the wall thickness either to the point of breaking (i.e., to the elongation at break limit) or until the pressure is discontinued. After discontinuing the pressure, however, the pipe walls do not return to their original thicknesses. Also, if the pressure is applied unevenly, or if there is a discrete area within the thermoplastic or thermoset pipe wall which is already thinner than the other areas, then the pipe will more easily burst in relation to the pressure buildup or in relation to the thinner wall portion. In order to alleviate such detrimental expansion and burst possibilities within thermoplastic piping materials, reinforcing materials have been developed to compensate for such problems. However, in the past, such piping materials have been limited primarily to hoses and short tubes (i.e., automobile tubing) which did not require the ability to withstand extremely high pressures.

It has now been found that the incorporation of certain textile reinforcement materials permit reduction of the diameter to wall thickness ratio for standard thermoplastic and/or thermoset materials by at least a factor of 1.5 (a ratio for any thermoplastic of at the most 1:17 in order to withstand a pressure of at least 80 bars). Preferably, then, the thickness of the inventive pipe walls should be no greater than about $1/17^{\text{th}}$ of the pipe diameter; more preferably no more than about $1/20^{\text{th}}$, and most preferably no greater than about $1/25^{\text{th}}$ of the pipe diameter. The term "withstand pressure" is intended to encompass the ability to prevent elongation of the entire pipe material to a point of breaking or weakening in discrete areas (i.e., thinning of certain areas to permit leakage). Such ability to withstand pressure is imperative since the utilization of high pressures internally provides a consistent and continuous force seeking equilibrium with the external pressures. Any excess thinning of the pipe material would therefore most likely result in bursting of the pipe due to physical requirements of equaling pressures. Such textile reinforcement materials thus aid in the reduction of elongation of the thermoplastic or thermoset pipe components upon application of high pressures therein. As noted previously, it has been determined that the elongation at break of such textile reinforcements provides the overall elongation at break exhibited by

the target pipe article, particularly upon the presence of such reinforcement materials between at least two distinct layers of thermoplastic or thermoset materials. In such a manner, the entire article relies primarily upon at least one textile reinforcement layer to provide the desired high elongation at break limit and the low crack propagation exhibited by the reinforced thermoplastic or thermoset material. Furthermore, such a reinforcement material also aids in providing an increased tear resistance to the overall pipe article which aids in reducing the chances of a breach in structural integrity as a result of external shear force application (i.e., earth tremors, and the like). Since there is strict reliance upon such properties exhibited and provided by the textile reinforcement layer, the amount of thermoplastic or thermoset materials can be substantially reduced with no reduction in reliability under pressurized situations. Also, if so desired, the user may still utilize a substantial amount of thermoplastic or thermoset material in combination with the sandwiched textile reinforcement layer or layers with confidence that, again, the inventive pipe article will exhibit improved and reliable pressure resistance, crack propagation resistance, and tear resistance.

Of enormous importance in this instance is the flexibility exhibited by the inventive pipes when subjected to external shear forces, for example earth tremors, and the like, as well as gravitational forces during storage, transport, and/or production. Such flexibility permits the pipes to exhibit some movement in relation to the shear forces generated by such external occurrences. In the past, as noted above, metal pipes suffered from the lack of flexibility in that the application of such external shear forces would result in the burst of certain pipes due to such external forces exceeding the shear force threshold possessed by the metal materials. Such flexibility is most suitably measured in terms of tear resistance to the overall pipe article. In general, metal pipes exhibit at most a tear resistance of about 6% (copper exhibits the highest such tear resistance), which is extremely low when the potential for very strong shear forces underground are significant (particularly in certain parts of the world prone to earth tremors, earthquakes, and the like). The thermoplastics and/or thermosets provide initial tear resistance measurements in excess of at least 20%, with a potential high measurement of more than about 100%, particularly upon incorporation of the sandwiched textile reinforcement material as discussed above. Thus, the inventive pipes should be able to withstand

enormous shear forces, at least better than metal pipes, due to their exhibited tear resistance and thus flexibility characteristics.

As it pertains to medium pressure applications (e.g., between 5 to 20 bars), although such thermoplastic and/or thermoset materials provide certain pressure resistances, in general the wall thickness required to withstand pressures of about 20 bars requires a wall thickness of at least about 6 millimeters (without the utilization of textile reinforcement materials as now taught). With the inventive pipes, a wall thickness of at most 5 millimeters may be practiced (of course, thicknesses greater than this limit may also be practiced, but, for this invention, the ability to reduce the wall thickness below 6 millimeters is quite significant and previously unattainable for resinous pipes). Even with such thicker walls (at least 6 millimeters) as taught with the aforementioned fiber-wound materials (polyaramid tapes, for example), the polymeric materials would not provide any resistance to crack propagation should a weakened area of the pipe produce such a burst point. There is a strong desire to increase the pressure resistance (and thus consequently, the elongation at break characteristics) of the target polymeric pipe material in order either to provide much thinner wall thicknesses without a loss in pressure resistance as compared with the standard polymeric materials alone, or to provide greater pressure resistant thin-walled pipes which are more reliable upon exposure to relatively high pressure situations (about at least 20 bars). Such desirable benefits have, again, been unavailable and unattainable through the utilization of fiber-wound reinforcement materials (for the reasons discussed above) and, more importantly, are not possible with thin-walled resinous pipes without any reinforcement materials combined therewith.

Apparently, upon application of internal pressure within such non-reinforced thermoplastic and/or thermoset piping materials, the materials expand in the direction dictated by the pressure therefore thinning the wall thickness either to the point of breaking (i.e., to the elongation at break limit) or until the pressure is discontinued. After discontinuing the pressure, however, the pipe walls do not return to their original thicknesses. Also, if the pressure is applied unevenly, or if there is a discrete area within the thermoplastic or thermoset pipe wall which is already thinner than the other areas, then the pipe will more easily burst in relation to the pressure buildup or in relation to the thinner wall portion. In order to alleviate such detrimental expansion and burst

possibilities within thermoplastic piping materials, reinforcing materials have been developed to compensate for such problems. However, in the past, such piping materials have been limited primarily to hoses and short tubes (i.e., automobile tubing) which did not require the ability to withstand extremely high pressures.

5 Thus, for both of such types of applications, as noted above, at least two layers of such thermoplastic and/or thermoset materials are present within the inventive thermoplastic and/or thermoset pipes. These layers are separated, at least in part, by a textile reinforcement material. The total wall thickness of the inventive pipe, as noted above, is dependent upon the discretion of the producer and in relation to the properties
10 provided by the textile reinforcement layer itself. If a thin-walled, low pressure pipe is desired, then the typical wall thickness may be anywhere from about 4 to about 15 millimeters. A higher elongation at break characteristic exhibited by the textile reinforcement permits lower thicknesses to be utilized. Such elongation at break characteristics are generally measured by the amount of force such textile reinforcements
15 may withstand. Thus, a textile exhibiting at least an elongation at break of about 2-3% (i.e., similar to that exhibited by steel but greater than for most thermoplastic and/or thermoset compositions) is desired. Of course, textile materials exhibiting far in excess of this elongation at break minimum are more preferred, with no real maximum level, only that which may deleteriously affect the overall stiffness of the product, thereby
20 potentially providing tear resistance problems. The elongation at break level for preferred textile reinforcements is determined by a number of factors, including the tenacity of the constituent fibers within the textile (a higher dtex provides a stronger textile overall), the angle of contacting relation to the direction of the pipe (angles of form 40 to 70° are preferred, while specific angles of between 45 and 65° and 50 and 55°
25 are more preferred, respectively. An angle of specifically 54°44' has been found to provide the greatest overall strength to the target pipe article. Thicker layers of textile reinforcement material also appear to provide stronger overall products, as do scrim and in-laid textiles.

 The term "textile reinforcement material" or "textile reinforcement" or "textile
30 reinforcement layer" simply requires a combination of individual yarns or fibers in a configuration which is an integrated two-dimensional article prior to incorporation between the at least two layers of thermally manipulated polymeric materials. Thus,

wound strips incorporated over a completed inner layer is not encompassed within such a definition. Nor are fiber-containing tape articles which are also wound around a formed polymeric pipe article. The specific textile reinforcement materials may be of any particular configuration, shape, and composition. The inventive textile reinforcements are present as at least a single layer of material with a total aggregate thickness of at least about 500 microns, preferably at least about 400 microns, more preferably at least about 300, and most preferably up to about 300 microns. Such textiles preferably exhibit a mesh structure between the two layers of thermoplastic and/or thermoset materials. In general, it is highly desired that synthetic fibers, either alone, or in conjunction with metal threads, be utilized within the reinforcement materials. Such synthetics are less likely to be susceptible to deterioration over time due to potential presence of bacteria, moisture, salts, and the like, within and around the pipes as they would be positioned underground. However, with the proper precautions of proper coating, finishing, and the like, natural fibers may serve this purpose as well. The preferred textile reinforcements may be knit, scrim, woven, non-woven, in-laid, and the like, in form, with scrim and in-laid textiles most preferred. Such forms are most easily produced and maneuvered during the actual pipe production procedure. With in-laid textiles, at least two layers are desired to have one layer oriented at one angle and the other its complement in relation to the direction of the target thermoplastic pipe. Thus, one layer would be placed with all yarns and/or fibers oriented at an angle of about $54^{\circ} 44'$ to the pipe direction, the other oriented at an angle of about $-54^{\circ} 44'$. In order to more easily hold such in-laid fabric layers in place, a thermoplastic film may be applied either between or on top of one or both layers. Such a film is preferably extremely thin (i.e., less than about 200 microns, preferably less than 100 microns, and most preferably less than about 50 microns) and, being a thermoplastic, will easily react with the outer layer of thermoplastic upon heating and molding around the inner layer/fabric reinforcement composite. Alternatively, sewn threads may be utilized to hold such multiple layers in place prior to, during, and after pipe production.

The yarns within the specific textile reinforcement materials may be either of multifilament or monofilament and preferably possess a relatively high dtex, again, to provide the desired tenacity and strength to the overall pipe article. A range of decitex of from about 200 to about 24,000 is therefore acceptable. Mixtures of such individual

fibers may be utilized as well as long as the elongation at break of the complete textile reinforcement material dictates the elongation at break for the complete thermoplastic and/or thermoset article. Multifilament fibers are preferred since they provides better adhesive properties and greater overall strength to the textile. The individual fibers may
5 be of polyester, polyamide, polyaramid, polyimide, carbon, fiberglass (silicon-based, for example), boron-derivative, and possibly, polyolefin, in nature. Again, natural fibers, such as cotton, wool, hemp, and the like, may be utilized but are not as trustworthy as the synthetic types listed above. Due to high processing temperatures associated with polymeric pipe extruding, it is highly desirable to avoid the sole utilization of low
10 melting- point polyolefin yarns. However, a plurality of individual fibers of such polyolefins (i.e., polypropylene, polyethylene, and the like) may be utilized in combination with the other synthetic fibers in order to improve adhesion upon melting of such yarns upon exposure to the higher temperatures present during the contacting of the textile reinforcement to the thermoplastic and/or thermoset inner and outer layers.

15 Fiberglass and boron-derivatives are preferred due to their strength characteristics and their alkaline resistance. The remaining fibers are also acceptable, including, most prominently, polyaramids, polyimides, carbon fibers, and polyesters. Polyesters are desirable from a cost standpoint while the remaining fibers are excellent with regards to strength.

20 Of particular preference within this invention are yarns of core-sheath types, as taught within U.S. Patent 5,691,030 to DeMeyer, herein entirely incorporated by reference. Such specific yarns permit breakage of the sheath components without affecting the strength of the core filaments therein. Such core filaments may be monofilament synthetic fibers (such as polyester, polyamides, polyaramids, polyolefins,
25 and the like), although, in one potentially preferred embodiment, at least a portion of such core filaments are metallic in nature (such as, preferably, copper, silver, gold, and the like) in order to permit conduction of electrical current and/or heat over the entire pipeline. Such metal threads, fibers, yarns, etc., are not limited to being core filaments and thus may be present as distinct in-laid, woven, knit, no-woven, placed, scrim,
30 components.

Such metallic components provide great strength as needed within the fabric reinforcement materials; however, they also may serve to provide other highly desirable

benefits for both the inventive pipes and the overall pipeline comprising such pipes. For example, such conductive components may permit the introduction of a low electrical current over the entire pipeline (through a continuous connection of metal components) or through certain segments thereof. In such a manner, a detection system may be implemented to determine where and at what time a pipe has burst or a leak is present. Upon interruption of the desired electrical signal (i.e., the specific amps of current), a valve may be operated to close off a certain portion of the pipeline until repairs are made. Such a system merely requires the connection of an ampmeter to the pipeline and integration of a valve in relation to the measured amperage flowing through the pipeline itself. Furthermore, with such a detection system, the ability to detect such problems from above-ground would be provided as well as a signal in relation to a low amperage count can be produced thereby signifying the specific location of the problem. Such a method thus facilitates detection and replacement of such thermoplastic pipes.

Additionally, in certain locations freezing temperatures may provide difficulty in transporting certain gases and liquids underground without the ability to provide heated pipes. The presence of metal yarns, etc., facilitates the generation of heat, potentially, within the desired pipes with, again, the introduction of certain selected amounts of current and/or heat over the metal components. The heat generated thereby may be utilized to effectively keep the desired pipes from freezing thereby permitting continuous transport therethrough.

Even upon utilization of a fabric reinforcement material configured at the preferred angles noted above in relation to the pipe direction (i.e., 40 to 70°, most preferably 55°), the addition of a cross-yarn within each repeating design, stitch, pattern, etc., configured at an angle of 0° in relation to the pipe direction is highly desired. Such a cross-yarn permits melting of the entire pipe structure at discrete places in order to allow for curvatures to be introduced within the pipeline without deleteriously affecting the strength of the remaining fabric reinforcement material or compromising the shear strength of the entire pipe composite, particularly at the specific bent place. Such an improvement again shows the benefits of thermoplastic high pressure pipes since such curvatures may be produced at any angle and on-site on an as needed basis. Historically utilized metal pipes required formation of necessary curvatures at the foundry; if the

angle of curvature was incorrect, new parts had to be produced to compensate for such a mistake. The inventive pipes permit on-site corrections if necessary.

It is desirable that the fabric reinforcement materials are in mesh form and thus exhibit open spaces between the constituent fibers and/or yarns therein. Such open space should be large enough to permit a portion of the heated liquid outer thermoplastic layer to adhere to the already formed inner thermoplastic layer therethrough and after cooling of the outer layer. In such a manner, not only is the three layer pipe stronger, the reinforcement materials are better held in place. Although larger open spaces between constituent fibers and/or yarns are preferred, the only requirement is that at least a portion of the outer layer exhibit some ability to adhere with the surface of the inner layer in contact with the fabric reinforcement materials. Thus, a range of preferred open space between individual constituent yarns of an area as low as 0.001 square millimeters and as high as about 1 square centimeter is desired.

The separate polymeric material layers and textile reinforcement layer may comprise any number of additives for standard purposes, such as antimicrobial agents, colorants, antistatic compounds, and the like. Such antimicrobial agents would potentially protect the inner lining from colonization of unwanted and potentially dangerous bacteria (which could potentially create greater pressure within the pipes if a proper nutrition source is present). Preferably, such an antimicrobial agent would be inorganic in nature and relatively easy to introduce within the thermoplastic compositions within the pipe. Thus, silver-based ion-exchange compounds (such as ALPHASAN®, available from Milliken & Company, and other types, such as silver zeolites, and the like) are preferred for this purpose. Colorants may be utilized to easily distinguish the thermoplastic layers for identification purposes. Any pigment, polymeric colorant, dye, or dyestuff which is normally utilized for such a purpose may be utilized in this respect for this invention. Antistatic compounds, such as quaternary ammonium compounds, and the like, permit static charge dissipation within the desired thermoplastic materials in order to reduce the chances of instantaneous spark production which could theoretically ignite certain transported gases and/or liquids. Although the chances of such spark ignition are extremely low, such an additive may be necessary to aid in this respect.

Such fabric reinforcement materials provide the aforementioned resistance to expansion, swelling, and/or burst due to the application of extremely high internal pressures within the target thermoplastic pipe material. Preferably, the fabric reinforcement material is configured at an angle of about 55° ($54^{\circ} 44'$) in relation to the direction of the target pipe itself. In such a manner, the fabric provides the best overall strength and thus resistance to internal pressures due to its resistance to shear forces generated by the internal pressure within the pipe. Depending on the amount of fabric utilized, however, the angle of contact may be as low as 0° and as high as 90° . With an angle configured in the same direction as the pipe itself, there is a higher risk of pipe burst due to the low shear force threshold provided by the fabric. Thicker fabrics may compensate for such shear force problems; however, the actual angle of contact should be from about 40° to about 70° , with the particular $54^{\circ} 44'$ angle most preferred. Furthermore, the number of fabric layers utilized may be plural to provide greater reinforcement strength. In such an instance, it is highly desirable that contacting layers of fabrics be configured at opposite angles of contact in relation to the pipe direction to accord, again, the strongest reinforcement possible. The utilization of a supplemental textile reinforcement layer oriented at an angle of contact with the pipe direction of either 0° or 90° imparts certain desirable properties to the overall pipe article. Most notably, crush resistance is provided to ready-made pipes which are necessarily wound on a reel for transport to an installation site. A 0° reinforcement angle provides the best stiffness to compensate for the weight generated by rolled pipes. Also, should an initial production of the inner layer be desired in roll form, the incorporation of such a 0° textile reinforcement component may alleviate crushing problems associated with such storage and transport. A 90° orientation improves upon the tear resistance of the final product.

Although only two specific layers of thermoplastic and/or thermoset materials are required, it is to be understood that more than two such layers are acceptable within this invention. Such additional layers may be of any type (and not necessarily thermoplastic and/or thermoset), including, without limitation, metal, ceramic, glass-filled plastic, rubber, and the like.

Other alternatives to this inventive article will be apparent upon review of the preferred embodiments within the drawings as discussed below.

As for the possible methods of forming these inventive pipe structures, one preferred embodiment involves an extrusion process that takes place in stages, with the pipe wall being progressively built up with each stage. The elongate reinforcing elements are therefore preferably applied to or embedded in the pipe wall between or during each of the extrusion stages. The pipe could, however, be fabricated in a single extrusion operation as well (as is discussed in greater detail within the drawings below), such as through providing a fabric construction and extruding such with the polymer material which forms the pipe wall, thereby permitting such fabric to become embedded within the polymer matrix automatically. The drawings below provide greater detail descriptions of the embodiments, however, it should be easily understood and appreciated that simple modifications and substitutions of the components of the preferred pipes are well within the scope of the invention.

Brief Description of the Drawings

These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings, where:

FIG. 1 shows an embodiment of the present invention illustrated as the pipe 10;

FIG. 2 shows a cross-section of the pipe 10 from **FIG. 1**;

FIG. 3 shows a partial cross-sectional view of an apparatus for forming the pipe from **FIG. 1**;

FIGS. 4A-H illustrate cross-sectional views of the apparatus and pipe from **FIG. 3**, illustrating the method of joining a reinforcing fabric with an inner wall;

FIG. 5 illustrates a partial view of a textile for use in forming the pipe from **FIG. 1** with the apparatus in **FIG. 3**;

FIG. 6 illustrates a textile for use as the reinforcing fabric for forming the pipe from **FIG. 1** with the apparatus in **FIG. 3**; and

Fig. 7 illustrates an apparatus for the in situ formation and placement of the pipe from **FIG. 1**.

FIG. 8 illustrates a cross-sectional view of another preferred embodiment of a pipe showing the utilization of multiple textile reinforcement components connected by tapered ends and placed around the circumference of the resin material.

FIG. 9 illustrates the inventive molding dom in cross-section at its first end (of high surface area) utilized within the inventive method of producing resin pipes.

FIG. 10 illustrates the inventive molding dom in cross-section at its second end (of low, smooth surface area) utilized within the inventive method of producing resin pipes.

FIG. 11 illustrates a side view of the inventive molding dom.

FIG. 12 illustrates the inventive molding in cross-section at its first end with the resin and textile reinforcement thereto applied at its initial stage of molding.

FIG. 13 illustrates the inventive molding in cross-section at its second end with the resin and textile reinforcement thereto applied and adhered together at its final stage of molding.

FIG. 14 is a transverse cross-sectional view of a pipe formed according to the present invention as well.

Detailed Description of the Drawings

Reference will now be made in detail to potentially preferred embodiments of the invention, examples of which have been illustrated in the accompanying drawings. It is to be understood that these are in no way intended to limit the invention to such illustrated and described embodiments. On the contrary, it is intended to cover all alternatives, modifications and equivalents as may be included within the true spirit and scope of the invention as defined by the appended claims and equivalents thereto.

Referring now to the figures, and in particular to **FIGS. 1** and **2**, there is shown a pipe **10** illustrating one embodiment of the present invention (wherein the thickness of the thermoplastic is in excess of 5 millimeters and thus is a high pressure pipe; as noted above, thermoplastic thicknesses of below 5 millimeters are also contemplated and in fact preferred for medium pressure applications). The pipe **10** generally includes an inner wall **110**, a reinforcing textile **120**, and an outer wall **130**. The inner wall **110** is preferably formed of a thermoplastic material, and has an inner passage surface **111** and an inner wall textile interface zone **113**. The inner passage surface **111** defines the interior of the pipe **10**. The outer wall **130** is preferably formed of a thermoplastic material, and has an outer surface **133** and an outer wall textile interface zone **131**. The reinforcing textile **120** wraps around the inner wall **110** and engages the inner wall textile

interface surface 133. The reinforcing textile 120 has a sufficient width to surround the inner wall 110, and have textile overlap sections 121 where the edges of the reinforcing material overlap around the inner wall 110. A textile locking system 123 is employed between the textile overlap sections 121 to prevent the ends of the reinforcing material 120 from separating. The outer wall textile interface surface 131 engages the reinforcing textile 120 and the outer wall surrounds the reinforcing textile 120. Such a textile locking system 123 may alternatively comprise an adhesive composition (such as, as merely example, heat-activated or pressure-activated adhesives) which permits a secure, long-term connection between the overlap sections 121 and thus prevents separation of the two sections upon pipe production and potential elongation caused by high internal pressures.

Referring now to FIG. 3, there is shown a cross section of an apparatus 200 for forming the pipe 10 in FIGS. 1 and 2. The apparatus 200 generally includes an inner wall die 210, a mandrel 220, a reinforcing textile guide 230, and an outer wall die 240. The inner wall die 210 has an inner wall die aperture 211. The mandrel 220 extends through the inner wall die aperture 211 and includes an outer surface 221 for forming the inner passage 111 of the pipe 10 and providing support to the inner wall 110 during the formation of the pipe 10.

Still referring to FIG. 3, the reinforcing textile guide 230 is positioned around the mandrel 220 after the inner wall die 210. The reinforcing textile guide 230 includes an inside textile guide 231 and an outside textile guide 232 for guiding the edges of the reinforcing textile 120 to position the reinforcing textile 120 around the inner wall 110. In one embodiment of the apparatus 200, the reinforcing textile guide 230 includes a joint material injector 235 that is located to insert a material between the overlap textile sections 121. In yet another preferred embodiment, the reinforcing textile guide 230 includes a closing roller 237 that presses the overlapping portions of the reinforcing textile 120 together.

Referring still to FIG. 3, the outer wall die 240 is located around the mandrel 220 and includes an inside die wall 241 and an outside die wall 245. The inside die wall 241 of the outer wall die 240 includes an inside die wall aperture 242 to receive the inner wall 110 and reinforcing textile 120 combination. The inside die wall aperture 242 has an inside die wall aperture taper 243 for assisting the inner wall 110 and reinforcing textile

120 combination to transition into the outer wall die 240. The outer wall die 240 also has an outside die wall 245 with an outside wall die aperture 246. A passage 223 in the mandrel 220 provides air pressure to the inside of the pipe 10 at a point after the outer wall die 240 forms the outer wall 130 on the pipe 10. A connecting chain 225 secures a plug 224 inside the pipe 10 seals to the mandrel 220 in order to maintain the pressure from the mandrel 220 within the pipe 10.

Referring now to FIGS. 1, 2, and 3, in operation, a thermoplastic material is extruded through the inner wall die aperture 211 onto the outer surface 221 of the mandrel 220 to form the inner wall 110 of the pipe 10. The outer surface of the mandrel 220 provides support to the inner wall 110 of the pipe 10 during the processes of applying the reinforcing textile 120 and the outer wall 130. After the inner wall 110 has been extruded onto the mandrel 220, the reinforcing textile guide 230 positions the reinforcing textile 120 onto the inner wall textile interface zone 113.

Referring now referring to FIGS. 3 and 4A-H, the inside textile guide 231 and the outside textile guide 232 guide opposing ends of the reinforcing textile 120 as the reinforcing textile 120 is positioned onto the inner wall textile interface zone 113. FIGS 4A-H illustrate the sequence of how the reinforcing textile guide 230 apply the reinforcing textile 120 onto the inner wall textile interface zone 113 of the inner wall 110 in a sequential manner. The inside textile guide 231 first applies one edge of the reinforcing textile 120 to the inner wall 110 of the pipe 10. As the inner wall 110 of the pipe 10 progresses along the extruding apparatus 20, the outside textile guide 232 continues to wrap the reinforcing textile 120 around the textile interface zone 113 of the inner wall 110. In this manner, the reinforcing textile 120 surrounds the inner pipe 110 in a way that reduces the possibility of wrinkles in the reinforcing textile 120 or air pockets between the inner wall 110 and the reinforcing textile 120.

Still referring to FIGS. 3 and 4A-H, in one embodiment a textile locking system 123, in the form of a joint material 123a, is employed between the textile overlap sections 121 of the reinforcing textile 120 to assist the reinforcing textile 120 to remain locked in an overlap position when the finished pipe 10 is subjected to internal pressures. The joint material 123a is injected between the textile overlap sections 121 by the joint material injector 235 just prior to the position that the outside textile guide 232 joins together the textile overlap sections 121. The joint material 123a can be the same type of

material that is used to form the inner wall 110, the outer wall 130, or a different material selected to help secure the textile overlap sections 121 from separating. In another embodiment, the joint material 123a is a tape, ribbon, strand, or the like that is placed into position between the textile overlap sections 121 prior to the textile guide 230 joining together the textile overlap sections 121.

In an alternative yet preferred embodiment, the textile locking system 123 is a mechanical locking system utilizing mechanical devices such as hooks, piles, or other mechanical mechanisms. In a version of the textile locking system incorporating hook devices, a plurality of hook devices extending up from the lower textile overlap section 121 into the upper textile overlap section 121, down from the upper textile overlap section 121 into the lower textile overlap system, or both. The textile locking system 123 using hook devices can use hook devices similar to the hook devices in a hook and pile closure system. In a version of the textile locking system 123 that employs a pile type element, the pile type element can extend from the lower textile overlap section 121 into the upper textile overlap section 121, from the upper textile overlap section 121 into the lower textile overlap section 121, or both. The textile locking system 123 using a pile type element can have a pile type element formed from the same fibers or yarns of the reinforcing material, and can also have the pile elements canted to angle back towards the center of the reinforcing textile 120. In another embodiment, the textile locking system 123 employing a mechanical device can incorporate the mechanical device onto a ribbon, strip, strand, or the like that is placed into position between the textile overlap sections 121 prior to the textile guide 230 joining together the textile overlap sections 121. The textile locking system 123 employing a mechanical device in the form of a ribbon, strip, strand, or the like, the locking system 123 can also be positioned below the lower textile overlap section 121 and extend up into both textile overlap sections 121, or above the upper textile overlap section 121 and extend down into both textile overlap sections 121. Additionally the textile locking system can employ both the joint material 123a and the mechanical systems described above.

Referring back now to FIG. 3, once the textile locking system 123 is located in place, the closing roller 237 presses the textile overlap sections 121 together in preparation for applying the outer wall 130. The outer wall 130 is formed around the inner wall 110 and reinforcing textile 120 combination by the outer wall die 240. The

inner wall 110 and reinforcing textile 120 combination enters the outer wall die 240 through the inside wall aperture 242 of the outer wall die 240. The inside wall aperture taper 243 assists the inner wall 110 and reinforcing textile 120 combination transition into the outer wall die 240. A thermoplastic material is extruded into the outer wall die 240 and surrounds the inner wall 110 and reinforcing textile 120 combination. The inner wall 110, reinforcing textile 120, and outer wall 130 exit the outer wall die 240 through the outside die wall aperture 246 in the outside die wall 245. The outside wall die 240 is illustrated in FIG. 3 as being perpendicular to the pipe 10; however, it is contemplated that the outside wall die 240 can be at an angle such that the inside wall a inside die wall 241 and the outside die wall 245 form an acute angle to the inner wall 110 and reinforcing textile 120 combination entering the outer wall die 240. This acute angle facilitates the forming of the outer wall 130 on the pipe 10 and helps reduce the tendency of the thermoplastic material to leak out of the inside die wall aperture 242.

Still referring to FIG. 3, air pressure applied to the passage 223 in the mandrel 220 exits into the interior of the pipe 10 after the outer wall 130 has been formed. The plug 225 inside the pipe 10 helps retain the pressure inside the pipe 10. A connecting chain 227 holds the plug 225 adjacent to the mandrel 220. The pressure applied within the pipe 10 prevents collapse of the entire structure as the three layer pipe 10 hardens into its final shape. After hardening, the plug 225 is removed and the resulting pipe structure 10 is ready for utilization in tandem with other such pipes (not illustrated) as an entire high pressure pipeline (not illustrated).

Referring now to FIG. 5, there is shown a partial view of a textile 300 for use as the reinforcing textile 110 illustrated in FIGS. 1 and 2. The textile 300 includes electrode elements 311 and 312, and resistive elements 320. As illustrated in FIG. 5, the electrode elements 311 and 312 are conductive materials that run parallel along the length of the textile 300 as the selvage yarns. The resistive elements 320 are woven around the electrode elements 311 and 312, and interlaced to form a fabric. As an example, the resistive elements 320 can be a yarn formed of a flexible core having a fine resistance wire or tape wound spirally thereon, or having a layer of carbon particles bonded thereon by a thermoplastic or resin binder. The electrode elements 311 and 312, and the resistive elements 320 are flexible to form a fabric that can be placed around the inner wall 110 as the reinforcing fabric 120 illustrated in FIGS. 1 and 2.

Referring now to **FIGS. 1-2 and 5**, by using the textile **300** in **FIG. 5** as the reinforcing fabric **120** in **FIGS. 1 and 2**, an electrical current can be applied to the electrode elements **311** and **312** of the fabric **300** when in place within the pipe **10**. The electrical current supplied to the electrode elements **311** and **312** passes through the resistive elements **320** and generates heat. In this manner, the pipe **10** can be used to apply heat to the contents of the pipe **10**, or to compensate for the loss of thermal energy from the contents of the pipe **10** to the exterior of the pipe.

Referring now to **FIG. 6**, there is shown another embodiment of a textile **400** for use as the reinforcing textile **120** of the pipe **10** in **FIGS. 1 and 2**. The fabric **400** generally comprises selvage yarns **430**, electrode yarns **411** and **412**, and resistive yarns **420**. The electrode yarns **411** and **412** are woven around the selvage yarns **430** such that a resistive yarn **420** separates each electrode yarn **411** and **412**. At each intersection of the electrode yarns **411** and **412**, the electrode yarns **411** and **412** are insulated from making an electrical connection to each other. At each intersection of the resistive yarn **420** with one of the electrode yarns **411** and **412**, the resistive yarn **420** is placed in electrical connection with the respective electrode yarn **411** or **412**. In this manner, an electrical circuit is formed having the electrodes **411** and **412** interconnected by a series of segments from the resistive yarn **420**, thus forming a parallel resistive circuit. The parallel resistive circuit can generate heat in a similar manner to the textile **300** by applying an electrical current between the electrode yarns **411** and **412**. Additionally, any break in yarn electrode **411** or **412**, will create a change in the electrical potential across the electrode yarns **411** and **412**, indicating a location of the break. Therefore, a break within the pipe **10** causing a break of one of the electrodes **411** or **412**, can be located by measuring the electronic potential across the electrode yarns **411** and **412**.

In addition to the textiles **300** and **400** illustrated in **FIGS. 5 and 6**, a traditional woven or knitted textile having thermal generating elements can be incorporated as the reinforcing textile **120** illustrated in **FIGS. 1 and 2**. For example, a traditional woven fabric having selvage yarns, pick yarns, and filling yarns, can incorporate the thermal heating aspects of the textiles **300** and **400**. The picks of a traditional woven fabric can be the resistive elements, and the selvage yards and/or fill yarns can be a conductive material. Alternatively, the fill yarns can be formed of a resistive material, and the pick yarns can be conductive yarns which are electrically supplied by conductive selvage

yarns and/or conductive fill yarns. In yet another embodiment, the resistive yarns can be a combination of pick and fill yarns.

Referring now to **FIG. 7**, there is shown an apparatus **500** for the in situ formation and placement of an embodiment of the pipe from the present invention. The apparatus **500** includes a transportation device **510** such as a truck, a trench or ditch digging device **520** located on the transport device **510**, and an apparatus for formation of the pipe **530** such as the pipe forming apparatus **20** in **FIG. 3**. A supply of reinforcing textile **540** (such as a roll of the reinforcing textile **120** in **FIG. 1**) is positioned with the transportation device **510** to supply the pipe forming device **530** with the necessary reinforcing material **120** to form the pipe **10**. Additionally, an extruding device **550** with a plastic supply **551** is positioned with the transportation device **510** for supplying melted material to the inner wall die **210** of the pipe forming apparatus **200** for forming the inner wall **110** of the pipe **10**. A second extruding device **560** with a material supply **561** extrudes material and supplies the material to the outer wall die **240** of the pipe forming apparatus **530** for forming the outer wall **130** of the pipe **10**. Although the two extruding devices **550** and **560** have been illustrated as a separate supply, it is contemplated that the two extruding devices could be a single extruding device.

Still referring to **FIG. 7**, the ditch or trench digging device **510** removes material from the ground for placement of the pipe **10**. The extruding apparatus **520** receives extruded material from the extrusion device **550**, reinforcing material **20** from the supply, and extruded material from the extrusion device **560** for forming the inner wall **110**, reinforcing textile **120**, and outer wall **130**, respectively, of the pipe **10**. The pipe **10** is positioned within the trench or ditch formed by the trench or ditch digging device **520** and earth is placed over the pipe **10** as necessary. The process is continuous allowing the transportation device **510** to form and place the pipe **10** in situ.

FIG. 8 thus shows four separate textile reinforcement materials **610**, **620**, **630**, **640**, each with individually tapered ends **612**, **614**, **622**, **624**, **632**, **634**, **642**, **644**, that have been arranged around the circumference of the target resin pipe **602**. Upon contacting of these materials **610**, **620**, **630**, **640**, as shown, the tapered ends **612**, **614**, **622**, **624**, **632**, **634**, **642**, **644**, overlap with each other and, upon introduction of molten resin which then cools, the reinforcement materials **610**, **620**, **630**, **640** thus adhere not

only together, but also with the resin materials 602, thereby providing a reinforced pipe 602.

FIG. 9 shows one preferred embodiment of an inventive molding dorn 700. The end shown 702 comprises a plurality of similarly shaped indentations 704 which thus creates a very large surface area thereon. FIG. 10 shows the other end 706 of the same preferred inventive molding dorn 700 of FIG. 9. The diameter thereof of the second end 706 is the same as that measured to the greatest extension of the indentations 704 of the first end 702. FIG. 11 thus shows the same preferred inventive molding dorn 700 of FIGs. 9 and 10, depicting the modification of surface area (through indentations 704) of the dorn 700. The number and amount of indentations 704 is gradually and continually reduced as one views the dorn from the first end 702 to the second end 706. In order to keep the dorn 700 in place during pipe production, any method can be employed including adhesion, magnetism, and the like. As shown in FIGs. 12 and 13, it is thereby easier for the resin components 708 to adhere to one another, or alternatively, for such resin components to become more thoroughly adhered thereto during molding to the textile reinforcement materials 710 by permitting the forcing through of the resin components 708 over the entire length of the dorn 700 during the molding step. As the first end 702 is of greater surface area than the other areas of the dorn 700, and particularly the second end 706, which is round in shape to produce the ultimately desired round shape of the pipe article. Pressure is applied to the resin components 708 and textile reinforcement materials 710 by a wider extrusion device (or mandrel 520 in FIG. 7). The pressure thus exerted presses the resin components 708 and reinforcement materials 710 to the dorn 700 during extrusion. The first end (702 of FIG. 9) is preferably heated to a temperature permitting the resin components 708 to be in molten state initially. After extrusion over the molding dorn 700, then, the molded pipe article is permitted to cool into its molded shape.

The inventive molding dorn may also exhibit or possess alternative or extra indentations or patterns for other benefits as well. For example, small corrugated patterns transferred from the molding dorn to the ultimate inner surface of the subject pipe can aid in reducing friction within the pipe itself if such pipes are utilized for the containment of cables (fiber optics, for example). Since such cables must be pulled through or pushed through the entire pipe system to effectuate such containment, and

such introduction is performed at high rates of speed, the need to potentially reduce the friction on the introduced cables (to reduce the chances of wearing of the cables themselves, for example) is noticeable. The modification of the molding dorn to provide such a corrugated pattern (or like alternative pattern for the same effect) is thus contemplated as at least one alternative in this invention.

With reference to FIG. 14, the present invention provides a substantially rigid pipe 810 comprising a pipe wall 811 formed from polyethylene. The pipe 810 includes a plurality of elongate reinforcing elements 812 arranged to extend in a direction longitudinally of the pipe 810, substantially parallel to the central longitudinal axis X.

10 The reinforcing elements 812 comprise cords of textile material which serve to stiffen the pipe against longitudinal bending.

The reinforcing cords elements 812 are interconnected and are embedded in the polymer matrix of the pipe wall 811 in two distinct layers 813, 814. The interconnection of the longitudinal cord elements 812 in each of the layers 813, 814 is by incorporation of the elements in a relatively open mesh fabric. The fabric in this instance is laid, but may equally be knitted, woven, non-woven or stitched or any combination thereof. By incorporating the reinforcing cords 812 in a fabric it is possible to embed a complete layer of the reinforcing elements in the polymer matrix of the pipe wall 811 in a single operation as the polymer material is extruded to form the pipe configuration. The two layers 813, 814 are spaced apart a distance d across the width of the pipe wall 811 such that one layer 813 is embedded proximate an outer surface 815 of the pipe and the other layer 814 is embedded proximate the inner surface 816. As the stiffening effect of the two layers 813, 814 increases with the distance d , larger spacing is desired to maximize the stiffening potential. The thickness of each reinforcing layer 813, 814 also plays a role in the degree of overall stiffening achieved. The fabric layers are themselves preferably more than about 1 mm thick; for example in the range of 1-3 mm.

The reinforcing textile cords 812 are arranged or laid upon one another to form a mesh fabric material such that a plurality of said cords extend substantially longitudinally on the pipe. Other cords 812 of the fabric criss-cross the longitudinal cords at an angle in the range of 45° to 90° with respect to the longitudinal axis, and preferably in the vicinity of the $54^\circ 44'$ theoretical optimum for radial reinforcement. In that way the reinforcing fabric can be adapted to reinforce the pipe for both longitudinal bending

strength and radial burst strength. The inwardly positioned layer 814 typically provides a better radial reinforcing effect than the outer layer 813, while the outer layer provides superior longitudinal stiffening than the inner layer.

5 The longitudinal stiffening elements 812, together with the rest of the fabric in each layer, is typically treated or coated (for example by dipping or spraying) with a substance, e.g., a resin or a polymer, to enhance adhesion or bonding between the reinforcing elements and the polymer matrix of the pipe wall 811. For example, the reinforcing elements may be pre-coated or impregnated with a resin or polymer corresponding to or compatible with the polyethylene matrix.

10 The fabric of the layers 813, 814 may be formed as a cylinder or as a substantially planar sheet for application to and embedding in the polyethylene matrix as it is extruded. The fabric material may further be treated by exposure to heat or other radiation to cure the resin/polymer coating and thereby stiffen or rigidify the reinforcing fabric.

15 The pipe 810 may be extruded in a number of separate stages such that the width of the pipe wall 811 increases with each extrusion stage. The layers of elongate reinforcing elements 812 are applied to and embedded in the pipe wall 811 in the course of the extrusion process. In one technique, a fabric sheet or cylinder of reinforcing elements is applied after each of the extrusion stages. At this time the fabric may also
20 undergo the curing process. During the next extrusion stage the layer of reinforcing cord elements is covered and embedded in the polymer matrix of the pipe wall. According to an alternative technique, the fabric of reinforcing elements may be extruded with the polymer material that forms the pipe wall and therefore be automatically embedded within the polymer matrix. At the conclusion of the extrusion process the pipe achieves
25 its final form and the polymer matrix hardens to produce the substantially rigid reinforced pipe of this embodiment of the invention.

Having described the invention in detail it is obvious that one skilled in the art will be able to make variations and modifications thereto without departing from the scope of the present invention. Accordingly, the scope of the present invention should be
30 determined only by the claims appended hereto.

CLAIMS

What we claim is:

1. A pipe comprising at least two distinct layers of thermoplastic material and at least one layer of reinforcement fabric material, wherein said fabric reinforcement material is sandwiched between said two distinct layers of thermoplastic material, wherein the elongation at break exhibited by said pipe is limited to the elongation at break exhibited by said fabric reinforcement material, and wherein the elongation at break of said fabric reinforcement material is at most 20%.
5
2. The pipe of Claim 1 wherein the elongation at break of said fabric reinforcement material is at most 15%.
10
3. The pipe of Claim 1 wherein the elongation at break of said fabric reinforcement material is at most 10%.
15
4. The pipe of Claim 1 wherein the elongation at break of said fabric reinforcement material is at most 6%.
- 20 5. An apparatus having an transportation device, a trench forming device, a pipe forming device, a reinforcing textile supply, and at least one extrusion material device associated with said transportation device, said pipe forming device having an inner wall die for receiving extruded material from the at least one extrusion material device and forming an inner wall, a reinforcing textile guide for receiving reinforcing textile from
25 the reinforcing textile supply and positioning the reinforcing material on the inner wall, and an outer wall die for receiving extruded material from the at least one extrusion material device, and wherein said trench forming device and said pipe forming device are positioned such that said pipe forming device positions a pipe within a trench formed by said trench forming device.

6. A pipe comprising at least one layer of thermally manipulated polymeric material and at least one reinforcement material, wherein the average wall thickness of said thermally manipulated polymeric material within said pipe is at most 5 millimeters,
5 wherein said pipe exhibits an internal pressure resistance of at least 5 bars.
7. The pipe of Claim 6 wherein said average wall thickness of said thermally manipulated polymeric material is at most 4 millimeters.
- 10 8. The pipe of Claim 7 wherein the wall thickness of said thermally manipulated polymeric material is at most 3 millimeters.
9. The pipe of Claim 8 wherein the wall thickness of said thermally manipulated polymeric material is at most 1 millimeter.
15
10. The pipe of Claim 9 wherein said reinforcement material is a textile
reinforcement
material.
- 20 11. The pipe of Claim 10 wherein said pipe exhibits an internal pressure resistance of at least 20 bars.
12. A pipe comprising at least two distinct layers of thermoplastic material and at least one layer of multiple reinforcement fabric materials, wherein said fabric
25 reinforcement materials are connected together and sandwiched between said two distinct layers of thermoplastic material, wherein the elongation at break exhibited by said pipe is limited to the elongation at break exhibited by said fabric reinforcement material, and wherein the elongation at break of said fabric reinforcement material is at most 20%.
- 30 13. The pipe of Claim 12 wherein the elongation at break of said fabric reinforcement material is at most 15%.

14. The pipe of Claim 12 wherein the elongation at break of said fabric reinforcement material is at most 10%.
15. The pipe of Claim 12 wherein the elongation at break of said fabric reinforcement material is at most 6%.
16. A method of producing a resinous pipe comprising at least one layer of thermally manipulated polymeric material, wherein said polymeric material is first heated and applied around a first end of a molding dorn having a first end and a second end as well as areas in between, and subsequently moved along the length of said dorn to said second end of said dorn and eventually cooled, wherein said dorn exhibits the same diameter throughout its entire structure, but exhibits a greater surface area at said first end than at said second end.
17. The method of Claim 16 wherein said dorn exhibits a reduction in surface area numerically from said first end through all areas in between said first end to second end and ultimately to said second end.
18. The method of Claim 17 wherein said dorn is substantially round in shape at said second end.
19. The method of Claim 16 wherein said resinous pipe comprises a reinforcement material.
20. The method of Claim 19 wherein said reinforcement material comprises at least two different components adhered to said resinous material.
21. The method of Claim 18 wherein said reinforcement material is a textile material.
22. The method of Claim 19 wherein said reinforcement material is a textile material.

23. A molding dorn comprising a first end and a second end with areas in between said first and said second end, wherein said dorn exhibits the same diameter over its entire length and wherein said dorn exhibits a reduction in surface area numerically from said first end consecutively through all areas in between said first end to second end and ultimately to said second end.

24. The molding dorn of Claim 23 wherein said dorn is substantially round at said second end.

25. A substantially rigid pipe having a wall formed from a polymer material and including a plurality of elongate reinforcing elements embedded in the polymer material of the pipe wall, characterized in that the reinforcing elements are arranged to extend in a direction substantially longitudinally of the pipe and are adapted to stiffen the pipe against longitudinal bending.

26. A pipe as claimed in Claim 25, wherein the elongate reinforcing elements extend at an angle in the range of 0° to 20° with respect to the longitudinal axis of the pipe.

27. A pipe as claimed in claim 25 or claim 26, wherein the reinforcing elements are arranged in at least one layer, with each said layer embedded at a substantially fixed or constant depth within the pipe wall.

28. A pipe as claimed in claim 27, including at least two layers of reinforcing elements, with each of said at least two layers being substantially spaced apart a distance across the width of the pipe wall.

29. A pipe as claimed in claim 28, wherein the innermost layer of reinforcing elements is embedded proximate an inner surface of the pipe wall and the outer most layer of reinforcing elements is embedded proximate an outer surface of the pipe wall.

30. A pipe as claimed in any one of the preceding claims, wherein a plurality of the reinforcing elements are interconnected with one another by incorporation in a fabric material.

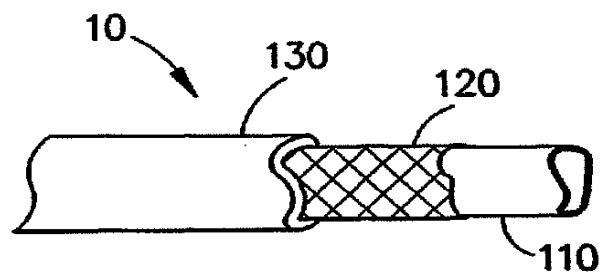
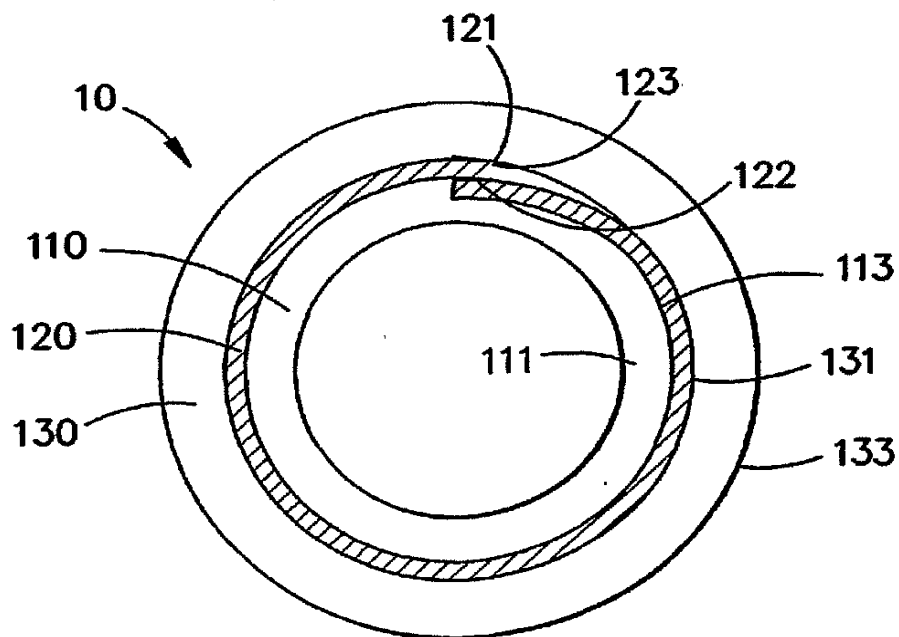
5 31. A pipe as claimed in claim 6, wherein the fabric material is formed of a woven, knitted, laid, non-woven or stitched fabric or any combination thereof.

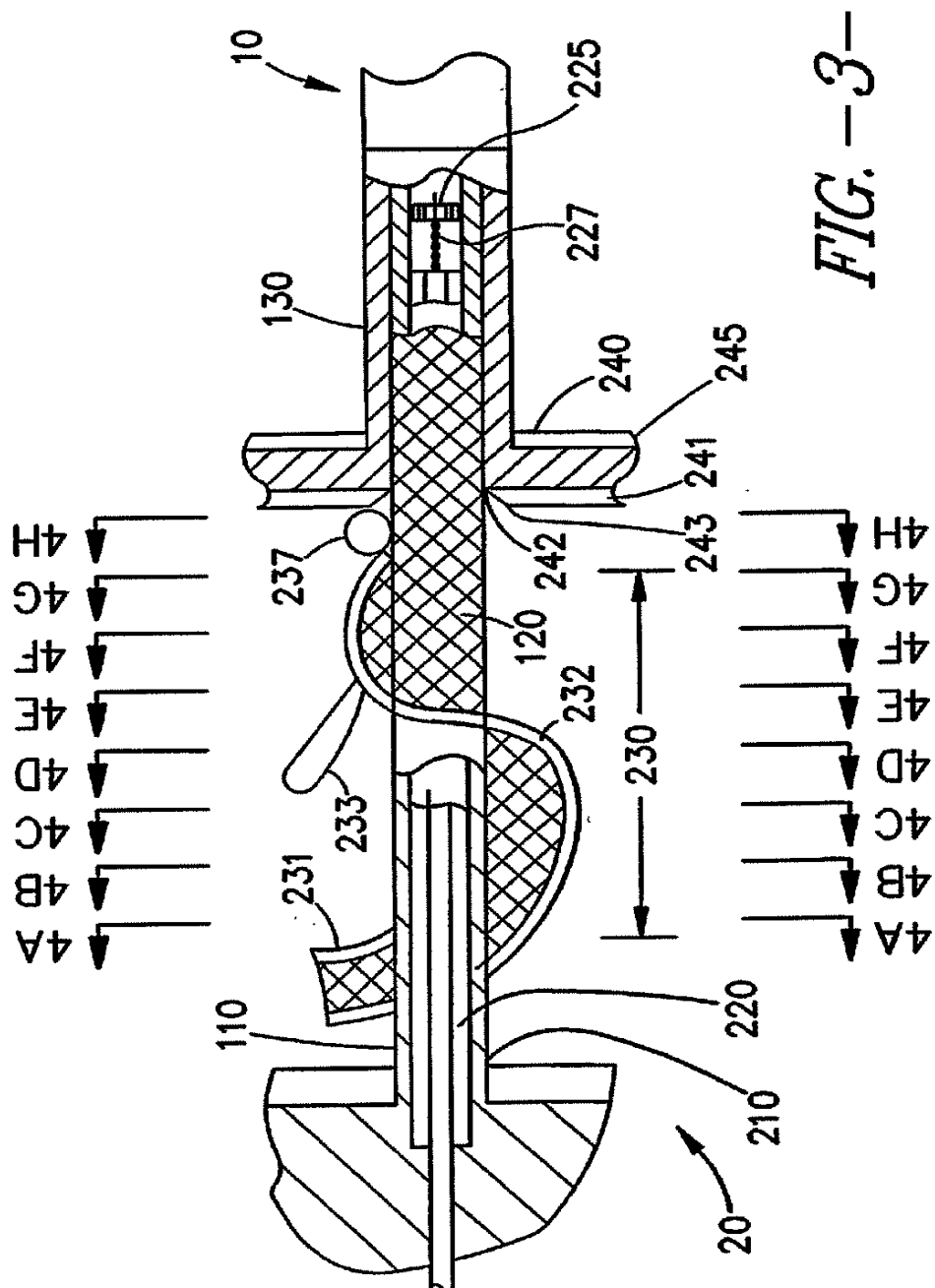
32. A pipe as claimed in any one of the preceding claims, wherein the elongate reinforcing elements comprise cords or yarns formed from textile fibers.

10

33. A pipe as claimed in claim 32, wherein the elongate reinforcing elements have undergone a curing or rigidifying process.

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*FIG. -1-**FIG. -2-*



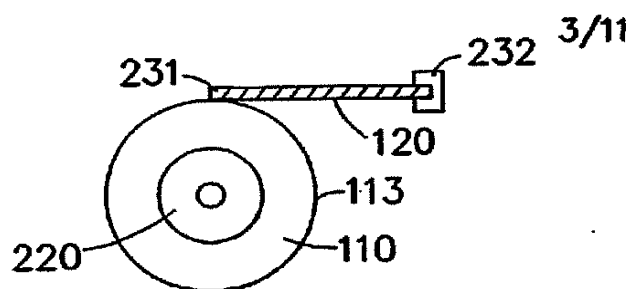


FIG. -4A-

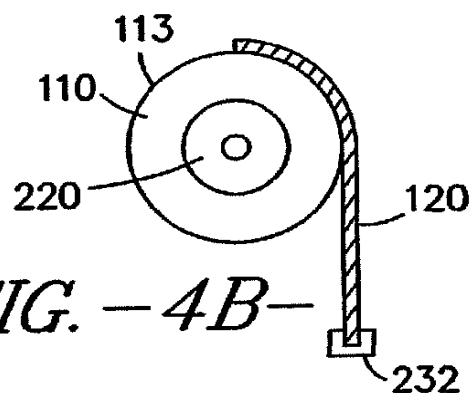


FIG. -4B-

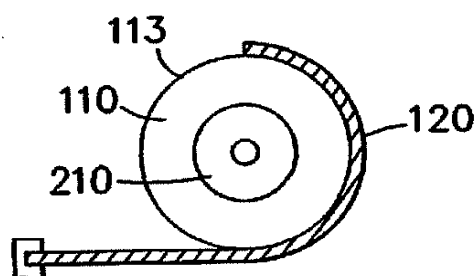


FIG. -4C-

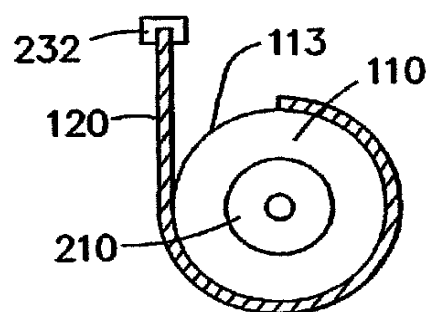


FIG. -4D-

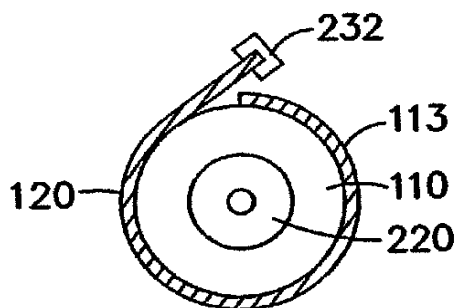


FIG. -4E-

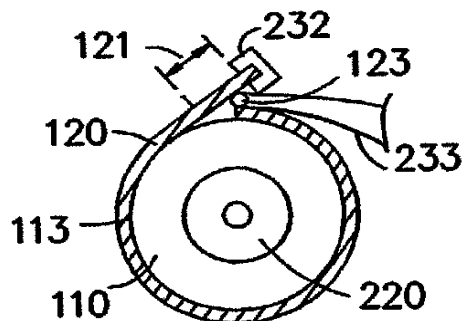


FIG. -4F-

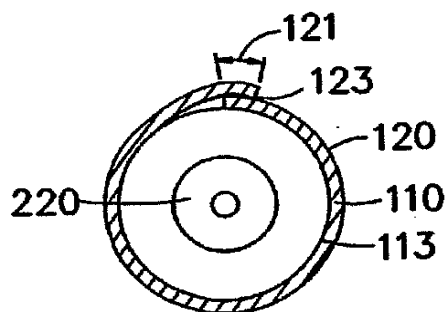


FIG. -4G-

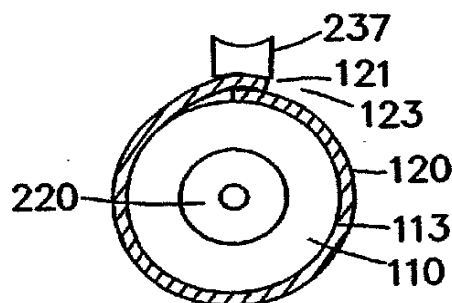


FIG. -4H-

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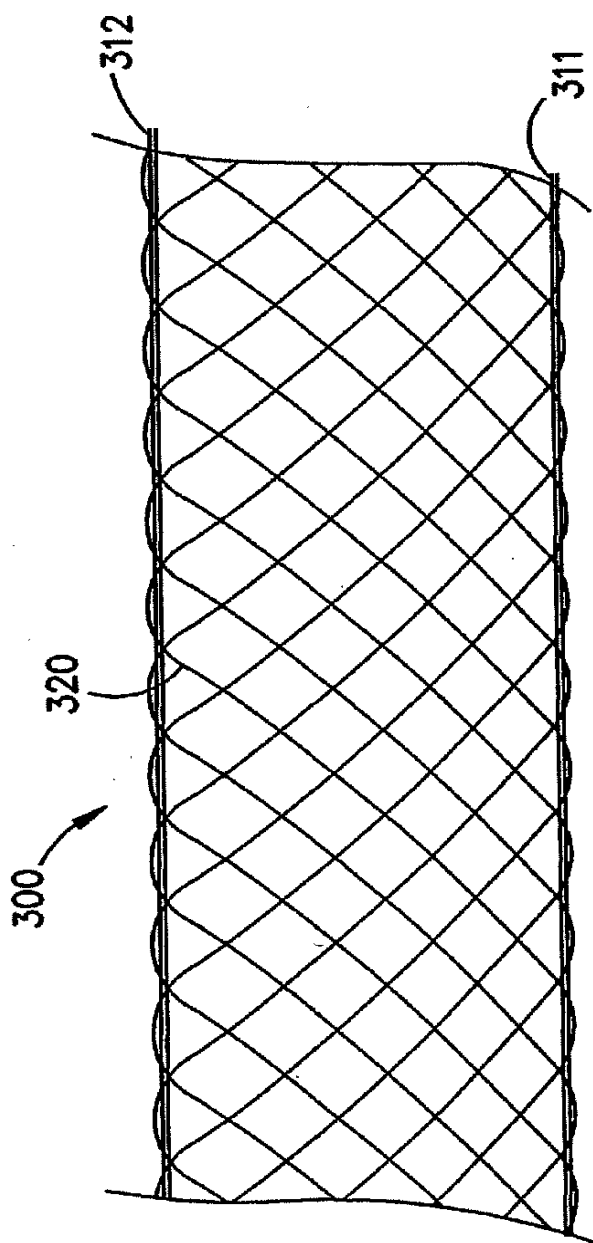


FIG. -5-

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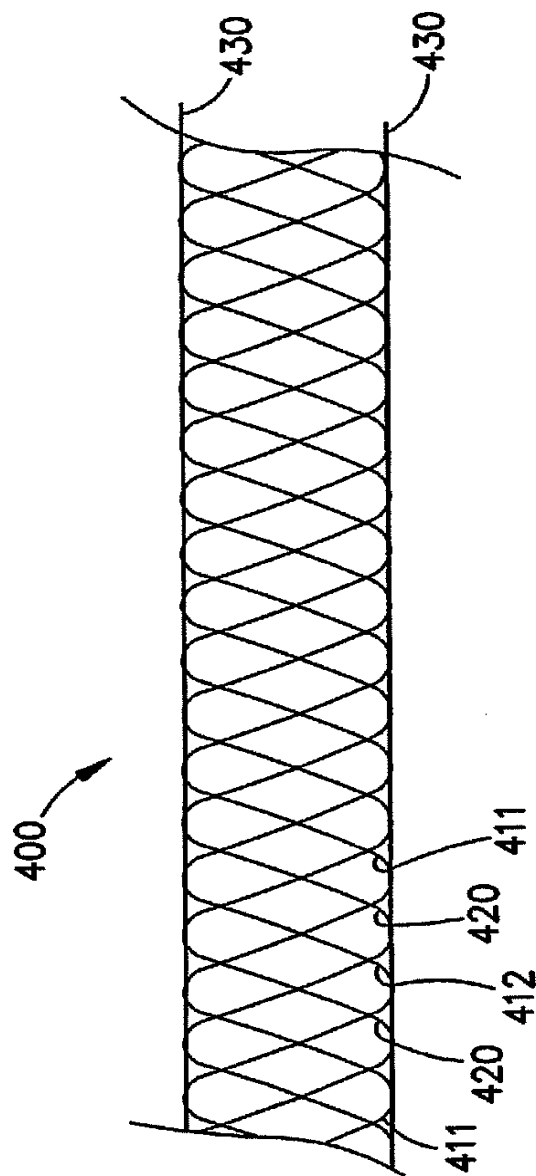


FIG. -6-

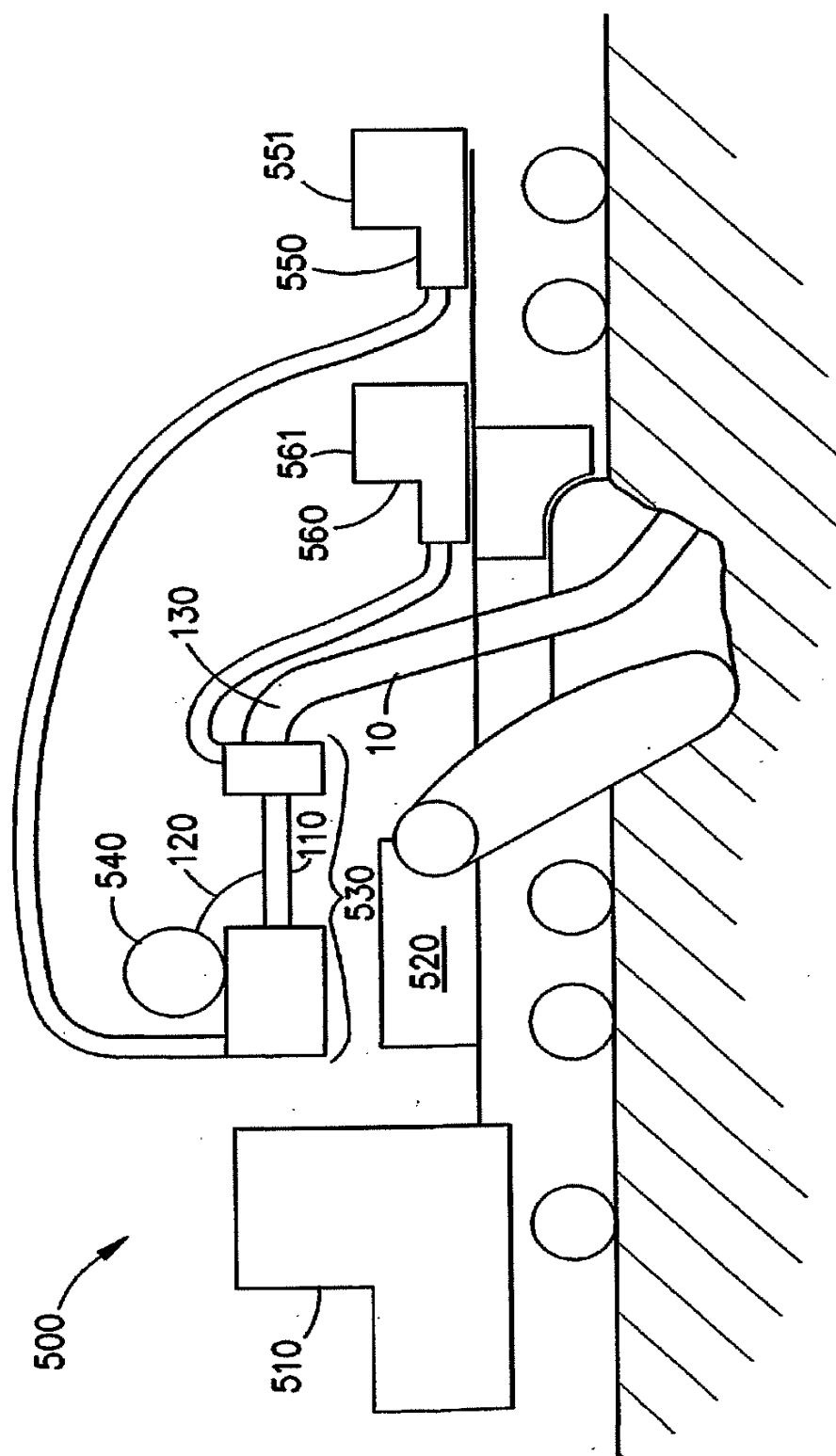


FIG. -7-

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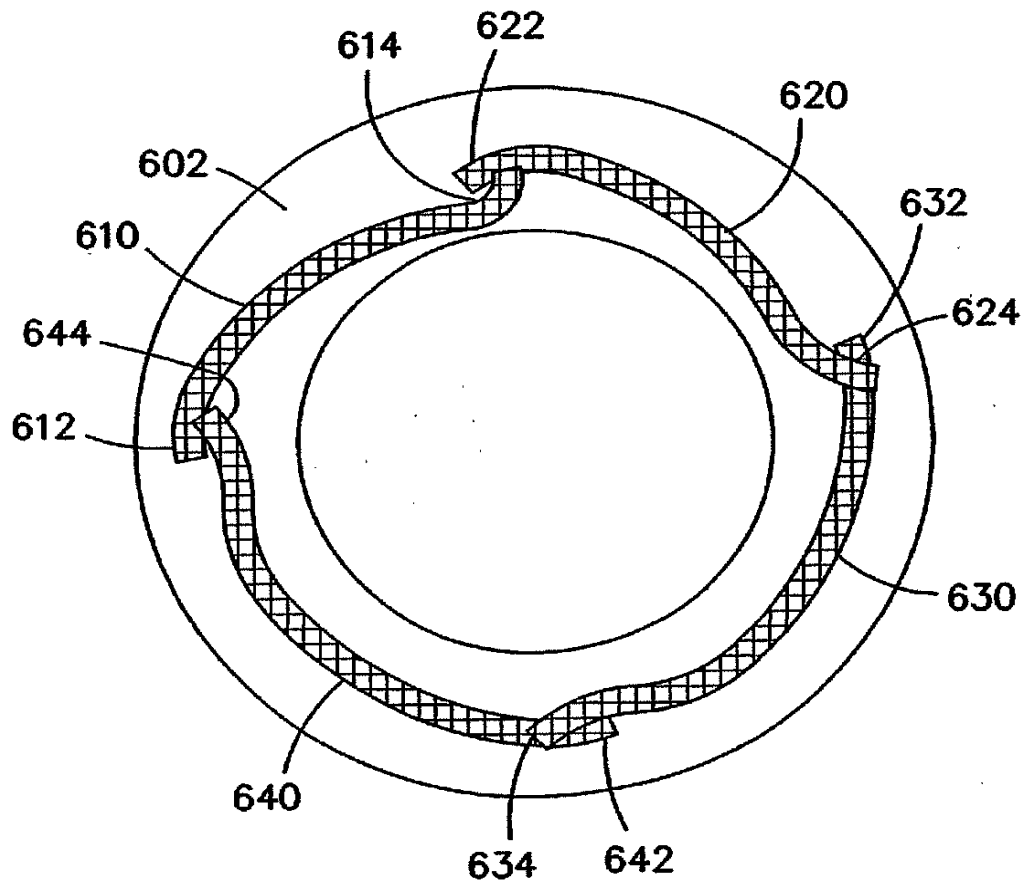


FIG. -8-

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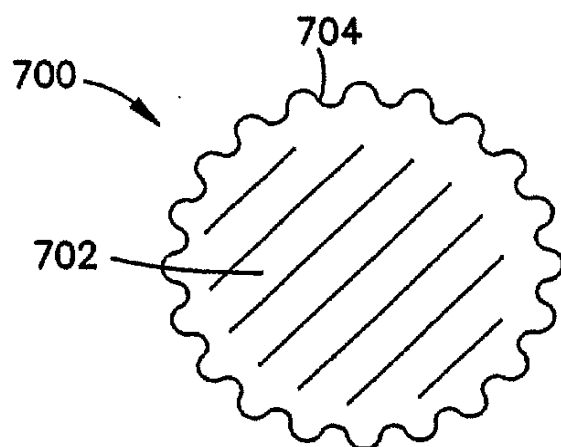


FIG. -9-

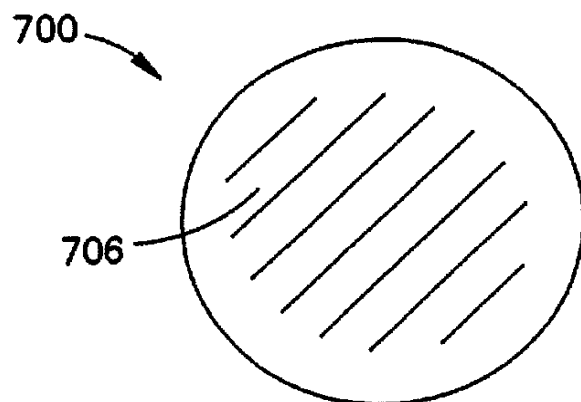


FIG. -10-

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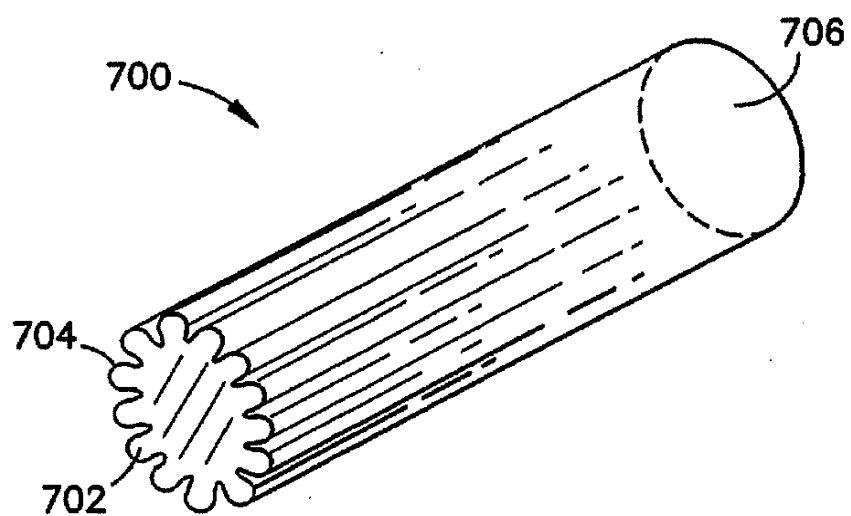


FIG. -11-

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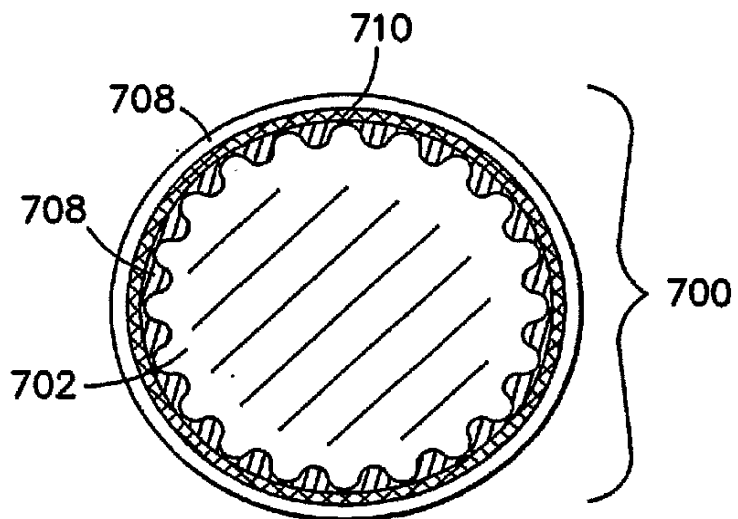


FIG. -12-

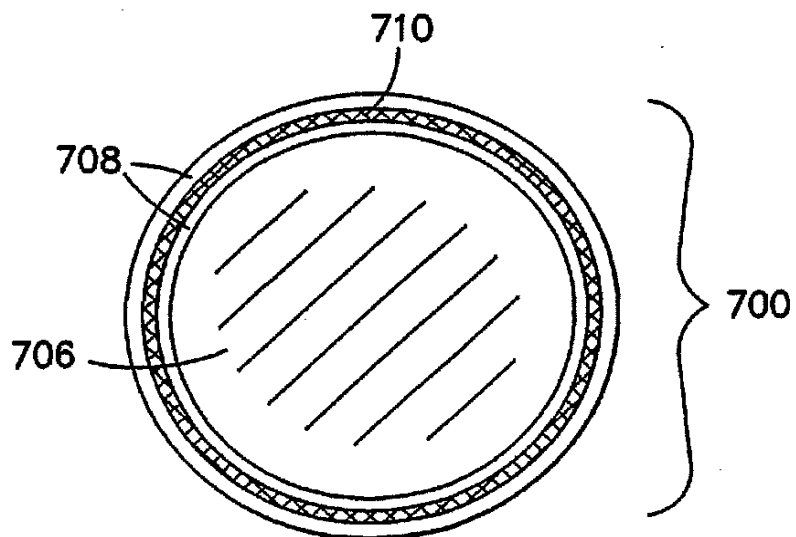
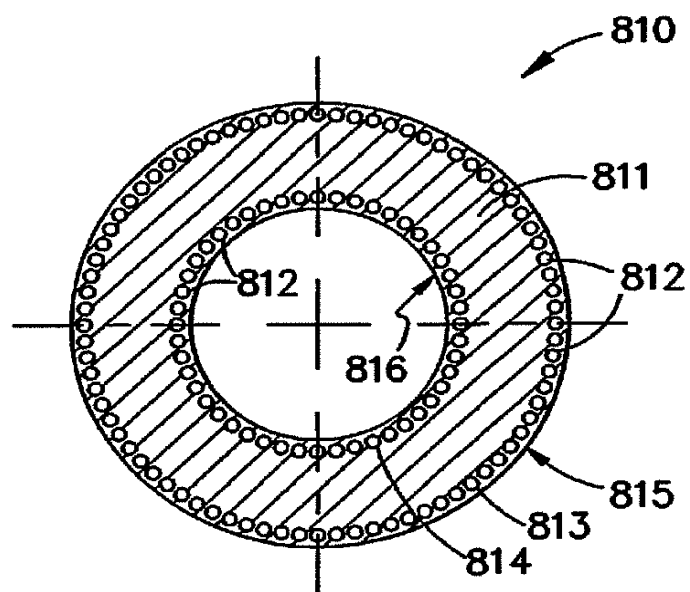


FIG. -13-

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*FIG. -14-*